FUZZY CONTROL

Example:

Consider a dynamic system of first order dynamics and delay with a transfer function

$$G(s) = \frac{1.2e^{-s}}{10s+1}$$

The reference signal is a unit step. Develop a fuzzy PI(D) type of controller for it and study its performance.

Solution:

The *Simulink* diagram of the system is shown below It is built in Simulink in the usual fashion by first opening Simulink with the command

» simulink

and then proceeding to use blocks in the appropriate block libraries.

How to cope with steady-state error? To reduce it to zero requires PI type of fuzzy controller. The integral part of the controller, drives the error to zero. If only two membership functions are used, the rule base becomes

- PI type FLC (velocity algorithm)
  - *– If e(k) is positive and Δe(k) is positive, then Δu(k) is positive*
  - *– If e(k) is positive and Δe(k) is negative, then Δu(k) is zero*
  - *– If e(k) is negative and Δe(k) is positive, then Δu(k) is zero*
  - *– If e(k) is negative and Δe(k) is negative, then Δu(k) is negative*

At this point one has to observe that in the simulation we are going to mix a continuous process and a discrete controller. In practice this requires A/D and D/A-conversions. Simulink

has so-called Zero-order hold block to handle the situation. For laymen it is also possible to skip this practical problem completely, because Simulink will, by default, allow to mix discrete and continuous signals.

The fuzzy controller uses error *e(k)* and change in *Δe = e(k)-e(k-1)* going into Fuzzy Logic Controller block. In the latter case, we need the appropriate transfer function block from Simulink block library. A simple calculation produces the following

$$\Delta e = e(k) - e(k-1) = (1 - z^{-1})e(k)$$

Since the input to the block is *e(k)*, the transfer function we want is

$$\frac{\Delta e(k)}{e(k)} = (1 - z^{-1}) .$$

Observe that the output is *Δu=u(k)-u(k-1).* The appropriate transfer function has *Δu* as the output and *u* as the input.

$$\Delta u = u(k) - u(k-1) = u(k) - z^{-1}u(k) = (1 - z^{-1})u(k)$$

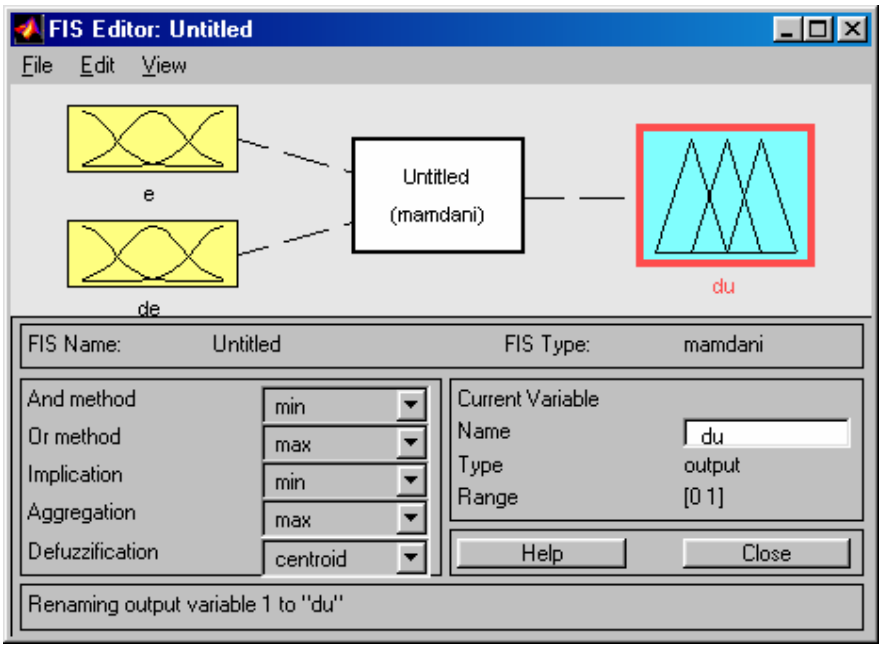
or

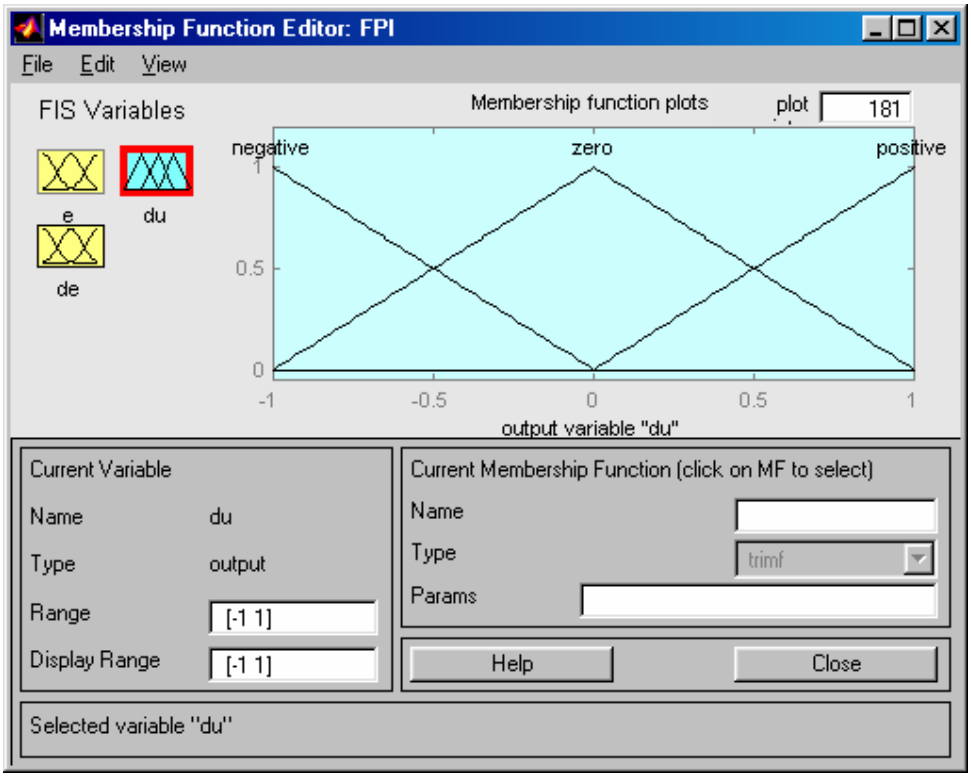
$$\frac{u}{\Delta u} = \frac{1}{(1 - z^{-1})}$$

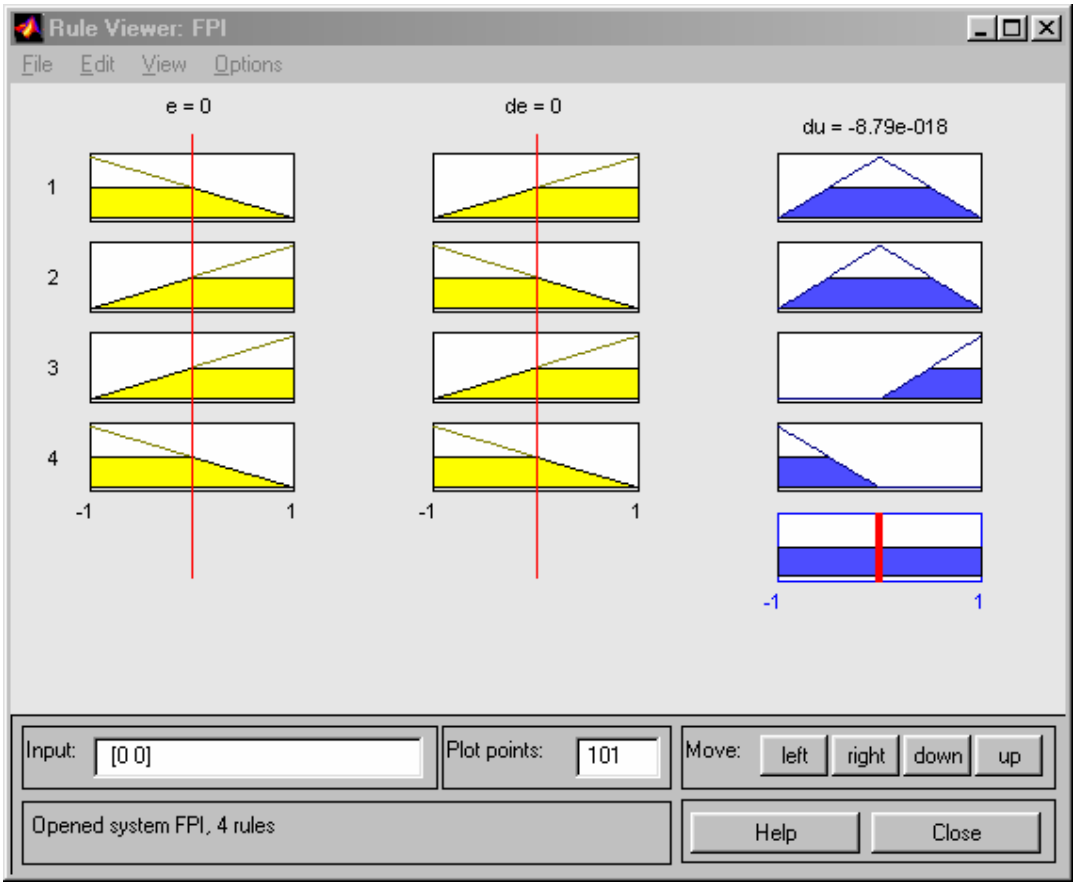
To design the fuzzy controller we open the Fuzzy Logic Toolbox GUI in the usual fashion by typing

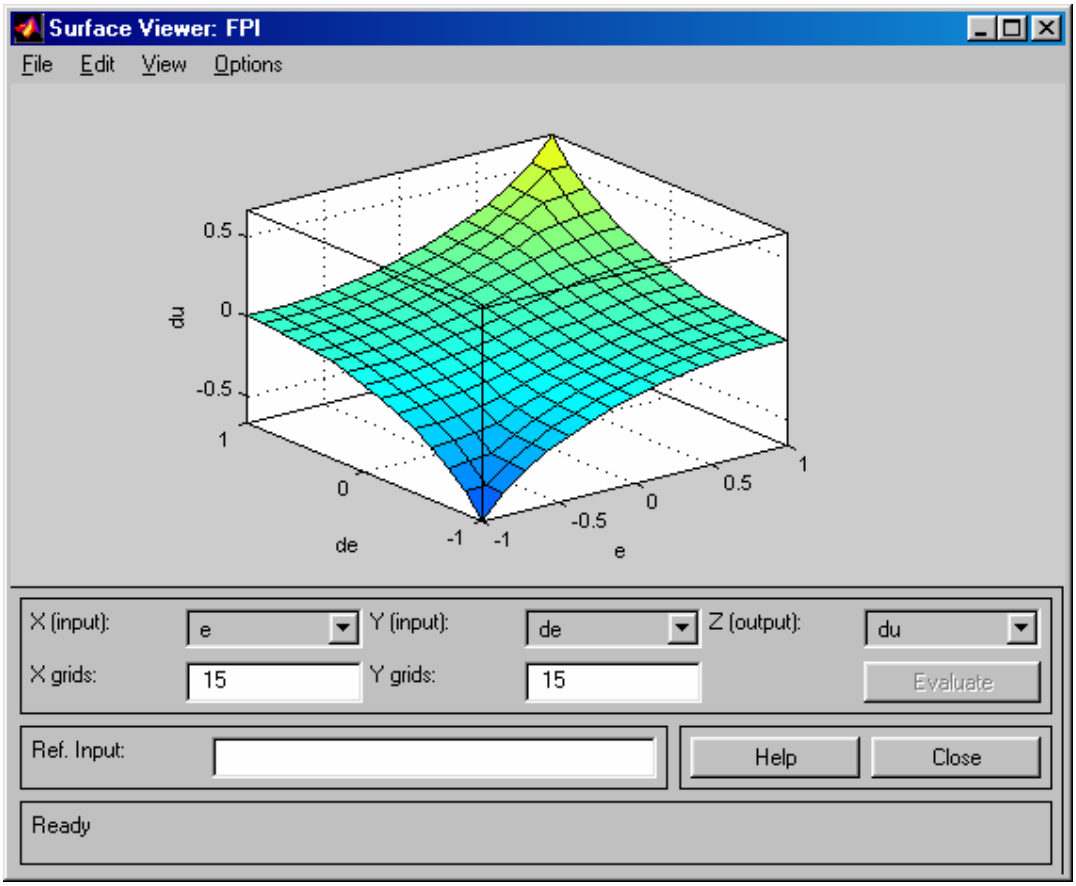
fuzzy

Set up a fuzzy system with two outputs and one output. For simplicity, use two, triangular membership functions at the input and three at the output. The resulting system is shown in the following figures.



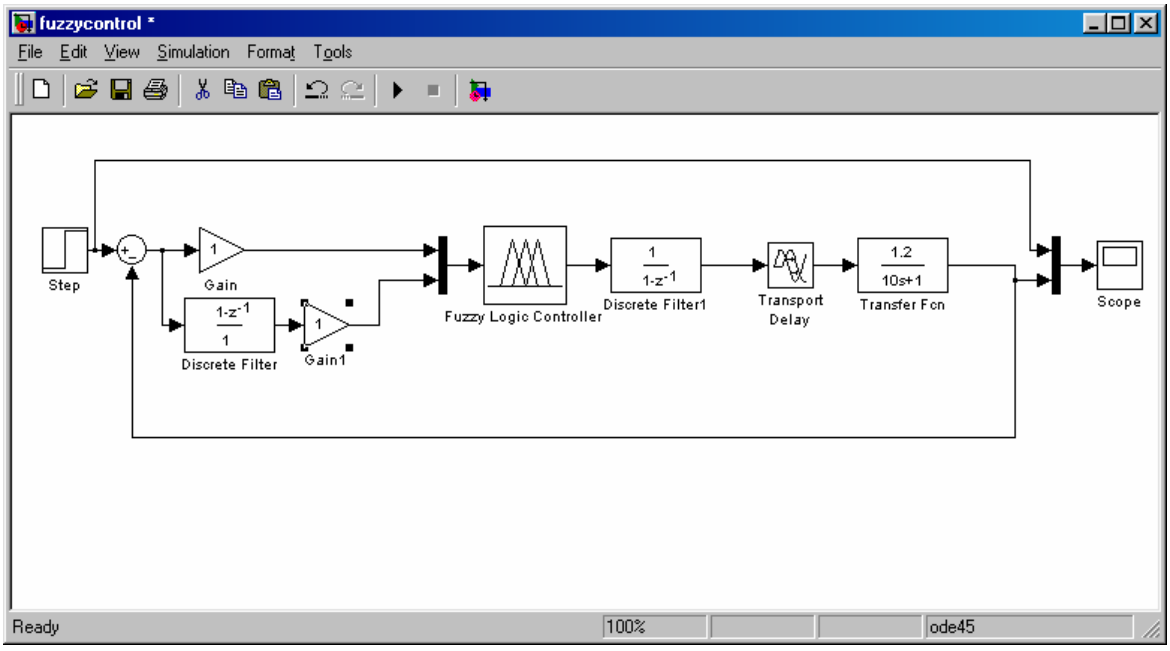



Rule Viewer: FPI
File Edit View Options
e = 0
de = 0
du = -8.79e-018
1
2
3
4
-1
1
-1
1
-1
1
Input: [0 0]
Plot points: 101
Move: left right down up
Opened system FPI, 4 rules
Help
Close

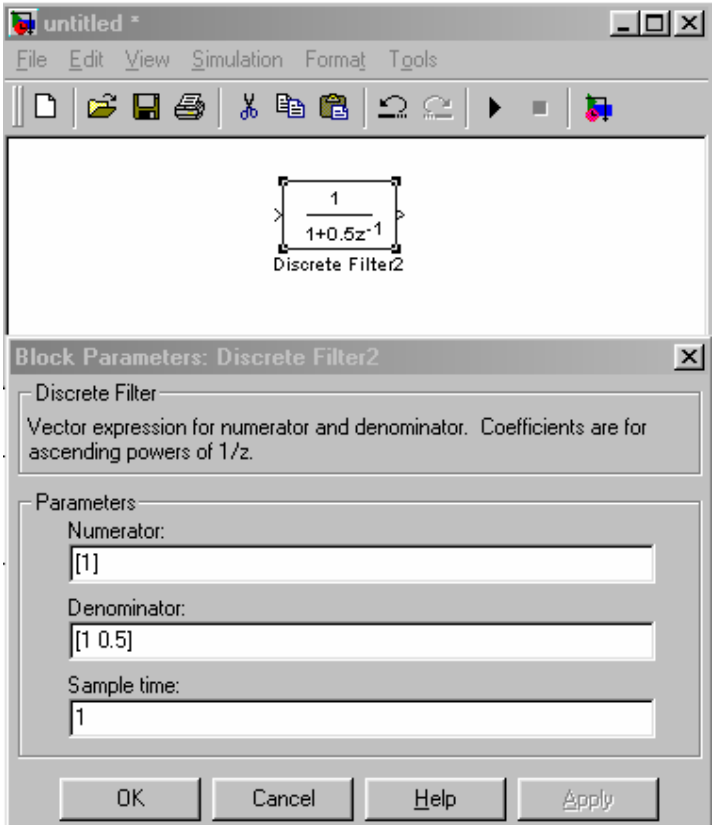


In order to transmit the knowledge of the fuzzy system to Simulink, save the FIS to workspace. Call it FPI.

Next go to Simulink and configure the overall system shown below.

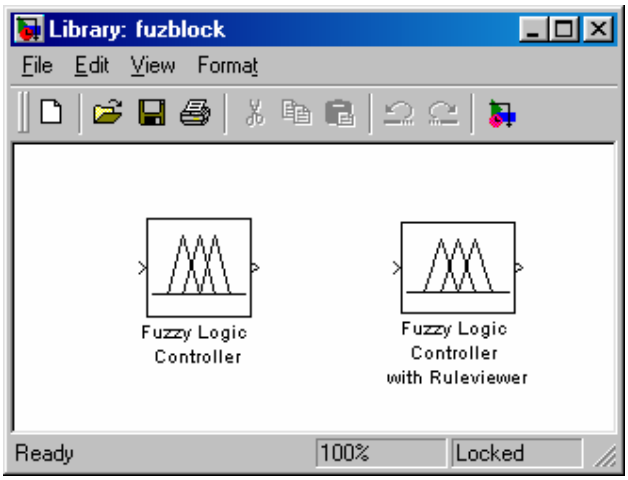


The two discrete filters are formed by changing Numerator and Denominator parameters appropriately.

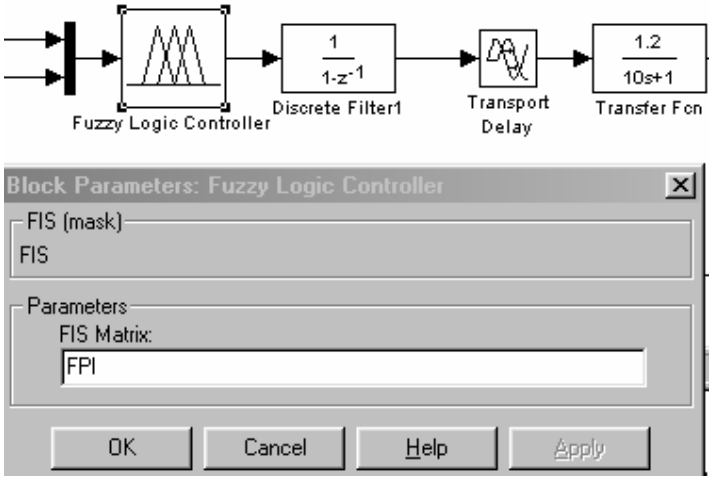


Remember that the Fuzzy Logic Controller needs two inputs, but can accept only one. Therefore introduce a multiplexer, *Mux*.

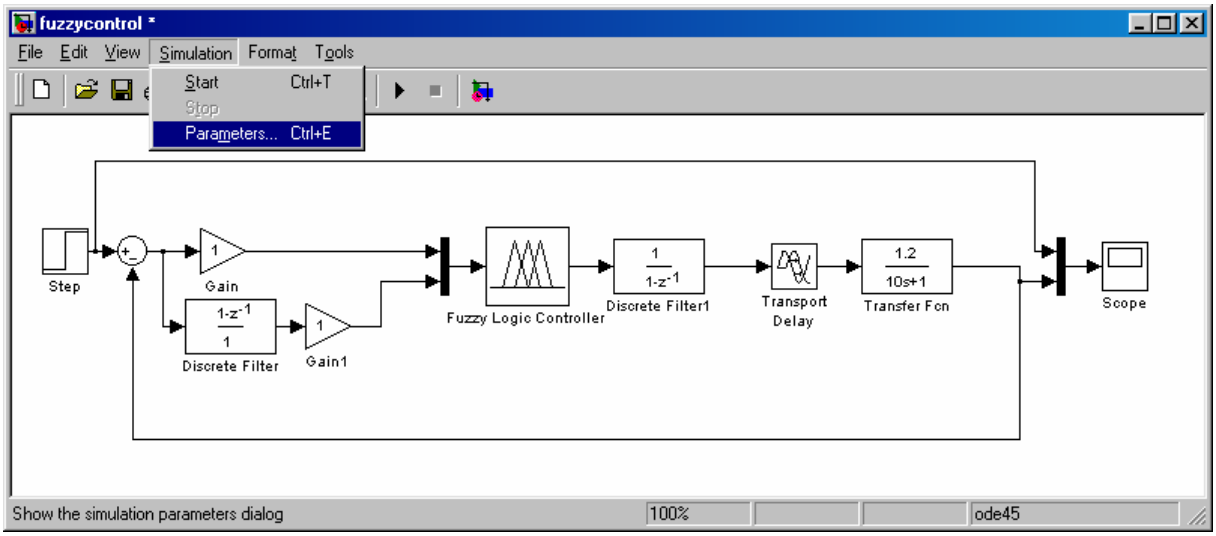
The fuzzy controller block library is found either by typing *Fuzblock* or opening first Blocksets & Toolboxes and then Fuzzy Logic Toolbox



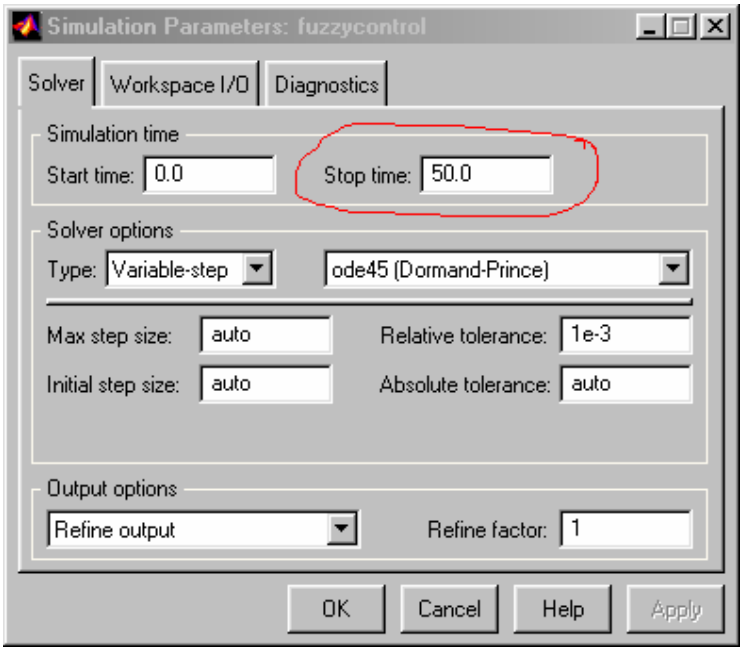
Once you move this block to the system configuration, you have to click it open and call it FPI.



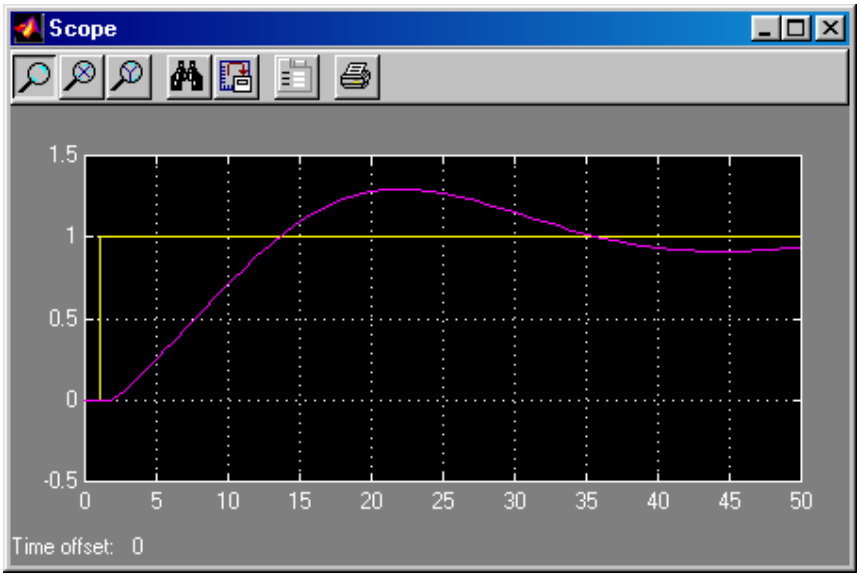
Now you can start simulation, but first adjust parameters as follows:



Open *Parameters* and change *Stop time* to 50 s.



Now start the simulation. The result is seen from the scope.



If a better response is needed, many ways can be tried. The gains can be changed, more membership functions may be added and their positions hanged.